Cryogenics Testbed Laboratory Flange Baseline Configuration

Marie Lei Ysabel D. Acuna[1]
Georgia Institute of Technology, Atlanta, Georgia 30332, USA

As an intern at Kennedy Space Center (KSC), I was involved in research for the Fluids and Propulsion Division of the NASA Engineering (NE) Directorate. I was immersed in the Integrated Ground Operations Demonstration Units (IGODU) project for the majority of my time at KSC, primarily with the Ground Operations Demonstration Unit Liquid Oxygen (GODU LO2) branch of IGODU. This project was established to develop advancements in cryogenic systems as a part of KSC's Advanced Exploration Systems (AES) program. The vision of AES is to develop new approaches for human exploration, and operations in and beyond low Earth orbit. Advanced cryogenic systems are crucial to minimize the consumable losses of cryogenic propellants, develop higher performance launch vehicles, and decrease operations cost for future launch programs. During my internship, I conducted a flange torque tracking study that established a baseline configuration for the flanges in the Simulated Propellant Loading System (SPLS) at the KSC Cryogenics Test Laboratory (CTL) – the testing environment for GODU LO2.

Nomenclature

AES	=	Advanced Exploration Systems
CTL	=	Cryogenics Testbed Laboratory
GODU	=	Ground Operations Demonstration Units
IGODU	=	Integrated Ground Operations Demonstration Units
IRAS	=	Integrated Refrigeration and Storage
KSC	=	Kennedy Space Center
LH2	=	Liquid Hydrogen
LO2	=	Liquid Oxygen
NASA	=	National Aeronautics and Space Administration
NE	=	NASA Engineering
SPLS	=	Simulated Propellant Loading System

I. Introduction

For the past five decades, the John F. Kennedy Space Center (KSC) has been the United States launch site for every National Aeronautics and Space Administration (NASA) manned space flight. After the end of the Apollo program in the mid-1970s, the Space Shuttle program became NASA's sole focus. A significant factor of the Space Shuttle program's cost was due to cryogenic propellants – over $20 million per year from 2006-2009. The loading operations and associated ground systems for the launch program were complex, and KSC's handling of cryogenic propellants in ground support equipment has slightly improved since the center's formation.

[1] NASA Intern, Cryogenics Testbed Laboratory, Kennedy Space Center, Georgia Institute of Technology.

Thus, the purpose of the Integrated Ground Operations Demonstration Units (IGODU) project is to develop advancements in cryogenics and technologies in command and control. These advancements would reduce lifecycle costs of future test program operations and space launch complexes. There are two branches to IGODU – GODU LH2 that deals with Integrated Refrigeration and Storage (IRAS), and GODU LO2 that deals with Autonomous Control.

II. GODU Integrated Refrigeration and Storage (GODU LH2)

At KSC, approximately half of the hydrogen that is purchased is lost due to operational methods, such as continuous heat leaks into the LH2 storage and transportation vessels. Therefore, the goal of GODU LH2 is to reduce the operation costs that are associated with the complex cryogenic propellant operations, as well as demonstrate effective handling operations. This includes the liquefaction, storage, and distribution of propellant.

III. GODU Autonomous Control (GODU LO2)

The Space Shuttle program required a great deal of specialized engineers due to the complexity of the cryogenic propellant loading operations. GODU LO2 is working towards reducing the amount of engineers that is needed to maintain and operate the ground and flight systems. This will be done through the use of health management and autonomous control technologies. GODU LO2's objectives are to demonstrate autonomous control of vehicle loading operations, as well as to demonstrate recognition of common system errors and recovery without the need for human oversight and intervention.

Figure 1. Simulated Propellant Loading System at the KSC Cryogenics Test Laboratory (Johnson, Notardonato, Currin & Orozco-Smith, 2012)

The testing environment for GODU LO2 is at the KSC Cryogenic Test Laboratory (CTL), and consists of a Simulated Propellant Loading System (SPLS) that mimics a system that would be found at a typical launch pad. The small scale SPLS – shown in Figure 1 – contains a liquid nitrogen system that simulates the LO2 system, a six kilo gallon propellant storage tank, a 500 hundred and two kilo gallon vehicle simulator tank, and control valve skids. A liquid nitrogen system is used for safety and cost purposes.

IV. Flange Torque Tracking Study

The purpose of the study, "Cryogenics Testbed Laboratory Flange Baseline Configuration," was to determine the relaxation of the flanges located at the KSC Cryogenics Testbed Laboratory (CTL). After a period of time and/or constant cryogenics cycles performed at the testbed, the flanges contract. This contraction crushes the seal that is in between the connecting flanges. When the system returns to ambient conditions, the flanges relax; however, the seal remains in its new, crushed, condition. This mismatch between the flange and the seal causes the torque applied to the bolts to relax.

During the study, we established a baseline configuration on each flange to verify that the flanges were torqued per KSC standards prior to the initial cryogenic cycle. This was done by torqueing each bolt on one side of the flange through the sequences shown in Figure 2 and Figure 3 below. While one person torqued the bolts with a torque wrench – either connected with a socket, deep socket, or crow's foot –

another person kept the bolt on the opposite side of the flange in place with a wrench. We then recorded the flat movement of each nut.

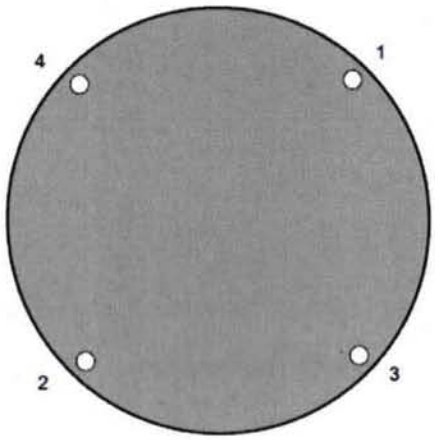

Figure 2. Bolt Torque Sequence for 4-Bolt Flanges

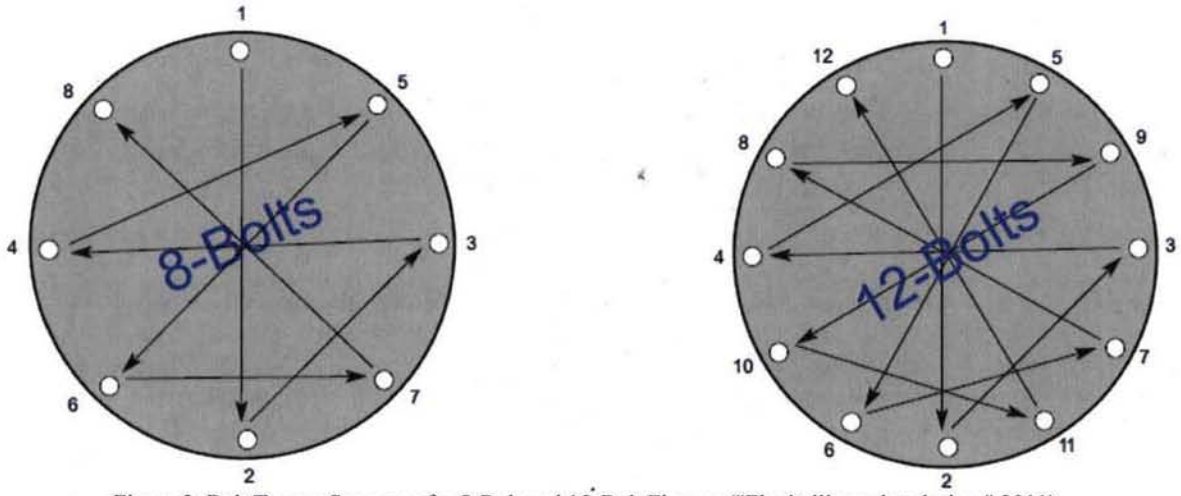

Figure 3. Bolt Torque Sequence for 8-Bolt and 12-Bolt Flanges ("Flexitallic gasket design," 2011)

Each flange on the SPLS varied from four to twelve nuts, with a flange rating that varied from 120 to 300 pounds per square inch. The amount of torque a flange would require was dependent on its flange rating, as well as its flange size which varied from one to six inches. The torque wrench used to torque the flanges were either set at forty-five foot-pounds, sixty foot-pounds, or 100 foot-pounds.

V. Conclusion

The Advanced Exploration Systems (AES) program aims to develop new technologies that would enable future human exploration beyond Earth's low orbit. The Integrated Ground Operations Demonstration Units project is working towards maturing technologies and cryogenic operations techniques. Advanced cryogenics systems are needed to lower the life cycle costs of future launch operations, and make the access to space more reliable and affordable. IGODU is divided further into two demonstration units – GODU LH2 and GODU LO2. During my internship, I was involved primarily with GODU LO2 and conducted a flange torque tracking study. We established a baseline configuration for

every flange in the SPLS at the KSC Cryogenics Test Laboratory. I cannot comment on the conclusion of the final study, because I only performed the first phase of the project during my time here at KSC. In the future, the CTL will be performing torque checks on each flange in the SPLS after each cryogenic cycle run.

Internship Experience

This spring, I had the opportunity to intern for the NE Cryogenics and Propulsion Branch at NASA Kennedy Space Center (KSC). During this internship, I was involved in the AES' Integrated Ground Operations Demonstration Units (IGODU) project, as well as Rocket University's Neo. Both projects provided me with opportunities to conduct my own research and evaluate engineering issues. I acquired new software skills, such as proficient knowledge in Pro-E. In addition, I gained knowledge of cryogenic propellant operations and became familiar with ground system equipment and tools. I developed a greater understanding of what the real world is like outside of school, and learned things that I would not have learned in a normal classroom setting.

After spending several months at KSC, I developed an even greater appreciation for NASA, its history, and the intelligent people who work here. Every person I met was very welcoming to me, especially those in my branch. I cannot express how grateful I am for the enormous amounts of assistance and advice that they have given me. I am blessed to have had the opportunity to be a part of such an inspirational program.

References

Flexitallic gasket design criteria. (2011). Retrieved from http://www.flexitallic.com/files/brochures/broDesignCriteria.pdf

Johnson, R. G., Notardonato, W. U., Currin, K. M., & Orozco-Smith, E. M. (2012, September).*Integrated ground operations demonstration units testing plans and status*. Presentation delivered at the AIAA space 2012 conference and exposition, Pasadena, CA.

Johnson, R. G., Notardonator, W. U., Currin, K. M., & Orozco-Smith, E. M. National Aeronautics and Space Administration, Kennedy Space Center. (2012). *Integrated ground operations demonstration units testing plans and status*. Retrieved from American Institute of Aeronautics and Astronautics website: http://arc.aiaa.org/doi/pdf/10.2514/6.2012-5247